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Evaluation of Soil Physicochemical Properties of Oil Spill Remediation Project in Kegbara-Dere Community, Rivers State, Nigeria.

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Abstract- This study was designed for the assessment of physicochemical properties of soils from oil polluted environs in Kegbara-Dere (K-Dere) Community, Gokana LGA, Rivers State, Nigeria. Soil samples were collected from four sites marked A (B-Dere), B (Kpor), C (Bomu), and D (Bera) representing different areas across K-Dere and environs, where remediation exercise were carried out between 2006-2008. Three of the sites A, B, C were heavily oil contaminated and site D used as control wasn't oil spill soil. At each of the sampled sites, soil samples were collected from two points at a distance of 100 meters, and in two depths, 0-15 cm and 15-30 cm using soil auger. The samples were analyzed for the determination of the rate of physicochemical parameters using standard analytical techniques. Descriptive statistics which includes mean, standard deviation, coefficient of variability and analysis of variance (ANOVA) were employed to summarize the data. The results of the statistical analysis showed that there were significant different at ($P<0.05$). The oil polluted soils had higher Clay (>60.0%) and lower sand and silt contents than the control site. Soil mean pH varied between 5.94±0.42 in the control and 7.16±0.63 in the oil polluted soils. Total nitrogen (N) content of the oil spilled soils ranged from 0.57±0.74 to 1.09±0.81% and is slightly higher than that of the control soil. This is reflected in the high value of organic matter (8.29±1.34%) in oil spilled soils. Available Phosphorus was quite high ranging from 37.11±2.98 to 78.42±3.97 mg/kg. Cation exchange capacity (CEC) varied between 13.88±1.27 and 90.95±2.40cmol kg−1. EC levels were moderate to high ranging from 198.11±2.98 to 968±93.34cmol/kg. All Anion (HCO3- , SO42- , CO32-) and exchangeable cations (Ca, Mg, K and Na) evaluated were far above the permissible limits set by WHO/FAO for agricultural soil. Average levels of Pb ranged from 241±54.45 to 349±70.71 mg/kg in the oil spilled soils and 117±6.36 to 286±1.41 mg/kg in the control. Mean concentration of Selenium (Sn) in the oil spilled soils varied between 29.53±2.94 and 43.7±1.40 mg/kg, and is slightly higher than the control (27.01±4.60 mg/kg), while Cd was found in trace amounts (1.32±0.98 mg/kg). These values were all far above the maximum tolerable limits set by FAO/WHO for agricultural soil. The results of this study revealed that the 2008 oil spilled remediation exercise carried out in K-Dere Community yielded a big positive result. Moreover, Aftermath, the recontamination of the area was observed to be on steady increase due to the accumulation of more pollutants arising from the oil industry in the area for over a decade without remediation.

Index Terms: Kegbara-Dere Soil-Physicochemical, K-Dere Remediation Project, Gokana Oil-Spill, Ogoni-Land Degradation, Heavy Metal Evaluation.

I. INTRODUCTION

Background of the Study:

Soils are major support systems of human life, and the earth's most important natural resource. It enables the growing of vegetation for feed, fiber, and fuel, it supports human food processing systems and has the potentials to help combat and mitigate climate change through absorption of carbon (Onwurah & Nwuke, 2021a). However, pollution of soils arising from anthropogenic activities such as oil spills or other contaminants/alterations in the natural soil environment made the role of soils seemed impossible (Udo & Ogunwale, 2021). There are many petroleum hydrocarbons polluted areas today due to incorrect use of oil products. Pollution of the environment by petroleum products is an inevitable consequence of oil production, processing, transportation and distribution (Robert, 2020). Robert added that large amounts of products handled on land every year create the possibility for land contamination. Large volumes of crude oil or petroleum products are transported across the world's oceans from producing areas to consumer countries. Consequently, a substantial fraction of this oil is released into the sea or on the land either by accident or during normal tanker operations (Pritchard & Costa, 2022).

Soil and water represent the first lines of recipients of oil pollution. Groundwater contamination by crude oil therefore, is becoming an increasing sensitive issue in Nigeria because most of the water supply is derived from shallow and unconfined aquifer.

Oil spillage in Nigeria especially in the Niger Delta area, of the southern part has become an issue of public concern due to its frequent occurrence which has been linked with petroleum exploration and development activities (Odu, 2022).

Oil spills have a significant impact on the natural resources upon which many poor Niger Delta communities depend. Drinking water is polluted, fishing, and farming are significantly impacted, and ecosystems are degraded. Oil spills significantly affect the health and food security of rural people living near the facilities. Additionally, oil spills and associated impacts of oil and gas operations have impacted the biodiversity and environmental integrity of the Niger Delta (Nwilo & Badejo, 2021). The oil reduces the soils fertility such that most of the essentials nutrients are no longer available for plant and crop utilization (Abii & Nwosu, 2022).

Oil spillage on farmlands in K-Dere and environs is as a result of crude oil exploitation, vandalism and oil theft. Aftermath, the soil (receptor) is soak up by the oil like sponges and prevents the lenticels of crops to absorb oxygen – hence oxygen starvation (Oyedejii, 2021). However, the crop withers and dies in large numbers thereby leaving the land barren and unproductive. As the spill occurs, oil contaminated farmlands may become anaerobic with increased solubility of iron (Fe) and manganese (Mn) to the extent that these potentially photo-toxic elements are absorbed by roots/plant. High oil concentration on soil not only reduces the amount of water and oxygen available for plant growth, but also interferes with soil-plant – water relationships through coating of root tissues and adversely affecting plant growth (Abii & Nwosu, 2022).

The K-Dere region of Rivers State suffers the dilapidating effects of crude oil pollution. Most of the soils where these spills occur suffer from loss of soil fertility through loss of soil organic matter, leaching of nutrients, loss of the nutrient – laden topsoil, changes in soil – pH, reduction in cation exchange capacity, Stalinization, water logging and other forms of soil degradation (Oyem, 2021). Soil fertility loss and declining crop yield among others are found to be indirect source of pressure on natural resources and community structure especially among the Ogoni rural poor (Pyagbara, 2022). Jike (2021) argued rather trenchantly that although oil companies have contributed minimally to the country's development, in K-Dere, oil spills have posed a major threat to the environment, which has led to total annihilation of the ecosystem. Thus, life in the area is becoming increasingly unbearable (Oyem, 2022).

Statement of Problem:

Pollution in Ogoni land occurs as a result of frequent and rampant cases of crude oil spills on farm and forest lands, rivers, creeks and other water bodies in the area. Popular cases of crude oil spills in Ogoni land include the Bomu Oil Well 2 of 1970 which polluted over 607 hectares of farm land belonging to Kegbara- Dere (K-Dere), B-Dere and Kpor communities (Kinako and Awiwaada, 2022). Other cases include, Mogho oil spill of 2004, SPDC'S 18 wellhead spill of 2006 at Kpor (NOSDRA, 2020), Bomu Oil Well 2, Ogoni oil rain of 2006, Kpor oil spill of June 16, 2008, and Kegbara-Dere crude oil seepage from one of Trans-Niger crude oil pipelines that cross the community (Pyagbara, 2022).

Across K-Dere and other Ogoni villages, evidences of oil spills are apparent in the soil and water. In January, 2020, many cases of oil spill in K-Dere and environs claims lives and properties and many injured (NOSDRA, 2020). The dilapidating effect of these spills has destroyed most farmlands in the area and renders it useless (Oyem, 2021).

Jike (2020) argued that although oil companies have contributed minimally to the country's development, however in K-Dere, their experience isn't applicable. Oil spills have posed a major threat to the environment, which has led to total annihilation of the ecosystem, thus life in the area is unbearable (Oyem, 2021). Live standing herbaceous crop biomass retards, and water infiltration into the soil reduces as a result of the hydrophobic characteristics of oil (Tanne & Anyanwu, 2021). Crude oil spill reduces percentage seed germination, plant height, stem density, photosynthetic rate, biomass and in most cases cause outright death of plants (Nyaman & Hester, 2022).

In area, the constituents of petroleum hydrocarbon release toxic gases under various conditions such as urbanization and industrialization, increased human and vehicular traffic, air pollution resulting from increased leakages in storage areas, industrial accident; slurry wastes and so on (Abowei, 2021). The indigenous people of K-Dere has been exposed to these dangerous gases such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NO), methane (CH_4), sulfoxides (SOx), ammonia (NH_3), and hydrogen sulfide (H_2S). Some of the toxic effects of these gases include apnea, progressive dyspnea, lachrymation, excessive salivation, grunting, anorexia, emaciation, dehydration, bronchitis, infarction, kidney failure and necrosis of skeletal muscles, to mention but a few (WHO, 2021). Therefore, this study investigated the effectiveness or success rate of the remediation work done in the area in the past and how it can be improved for the survival of the people.

Aim and Objectives of the Study:
The study evaluated the effects of oil spillage on soil properties in the study area and determined the success rate of the remediation work done by SPDC in the year 2008. The specific objectives of the study are to:

i. analyze the physicochemical properties of oil spill polluted soils and non-oil spill polluted soils in K-Dere and environs.
ii. determine whether there are significant differences in the soil physiochemical parameters of the oil spill soils and the non-oil spill soils in K-Dere environs compared to WHO/FAO threshold for agricultural soils.
iii. evaluate the SPDC remediation effort and the level of damage that oil spill still has on the fertility and nutrient status of the community farmland.
iv. Investigate appropriate measures for the remediation and restoration of the soil quality.

Research Questions:
i. What are the conditions of the physiochemical properties of the oil spill polluted soils and non-oil spill soils in K-Dere and environ?
ii. Is there any significant difference in the soil physiochemical parameters of oil spill soils and non-oil spill soils in K-Dere compared to WHO/FAO threshold for agricultural soils?
iii. What are the effects of oil spill on the fertility and nutrient status of the community farm land?
iv. How can oil spill polluted soils be remediated and restored in the oil polluted area?

Significance of the Study:
The study would be of benefit to the farmers in K-Dere and environs, research institutes, Ministry of Environment and Agriculture, DPR and NGOs. The findings of the study would be of benefit to the farmers by furnishing them with the information they would adopt to improve their skills and knowledge in agriculture. It would also provide useful information that will assist the farmers adopt innovations that could bring about desirable changes for the development of agriculture as well as increase the farmers' production; which would invariably improve their income. The Study through its findings on technology application provides information which government would use for decision making, and creating innovation in the area of technology applications that would improve productivity of peasant farmers. The Study provided information which the Ministry of Agriculture can use to establish some policies, rules and regulations aimed at the survival and development of agriculture. Also Environmental friendly technologies for reclaiming the lost fertile soil were outlined, which if applied appropriately would enhance agricultural and socioeconomic activities of the community.

Scope and Limitation of the Study:
The research is limited to Analysis of soil, to determine the physicochemical properties of the selected oil spill contaminated sites and non-oil spill

site (control) in K-Dere community, Gokana L.G.A of Rivers State, Nigeria. The study also sought for the WHO/FAO threshold of soil physicochemical properties in agricultural soils, through the official gazettes of Ministry of Environment, Department of Petroleum Resources (DPR), Ministry of Agriculture, Journals and Magazines, which invariably are the representative or indication of the level of soil health, nutrient status and fertility of a healthy soil. The study therefore investigated the significance difference between the oil spill sites and non-spill sites compared to the WHO/FAO threshold in agricultural soils.

Moreover, the study did not expand its scope to accommodate the isolation of the microorganisms or its derivatives that could be efficient for the degradation of the contaminants in the soils across the study area, due to financial constraints and time frame of this study. However, the study strongly recommended bioremediation and phytoremediation technology as a silver bullet and best techniques for the recovery of the lost soils in K-Dere and environs.

II. METHODOLOGY

Types of Data Acquired and Sources:
Data acquired for this research were data on Total Hydrocarbon Content (THC) of the soil, Total Organic Carbon (TOC), Total Organic Matter (TOM), Heavy metals, Soil PH, Soil Texture, Electrical Conductivity (EC), Moisture Content, Total Nitrogen, Exchangeable Cations and Anions on Crude oil polluted soils. Also involved were data on non-oil polluted soil (control) and data on permissible limit of soil parameters on agricultural land as recommended by WHO and FAO.

Data for this research were sourced from primary and secondary sources. The primary sources of data were acquired from the soils in K-Dere through intensive field work and laboratory investigations while the secondary data were sourced from Textbooks, Journals, Newspapers, Magazines, Official Gazette of the Ministry of Environment and Agriculture, Department of Petroleum Resources (DPR), WHO, Research bodies and Agencies.

Sample Collection and Preservation:
Field sample collections for the study were carried in May, 2019 (dry season). Possible leaching or wash away of the soil physicochemical parameters were overcome. The samples were collected within two consecutive days so as to minimize alteration of the chemical or biological constituents. At each site, samples were taken at two depths, surface (0-15 cm) and subsurface (15-30 cm) using soil auger, and preserved in an acid prewashed cleaned and sterile polythene bags and subsequently transported to Umudike Root Crop Research institute, Abia State, the closest research institute in the area, where it was analyzed.

Sample Preparation:
Soil samples were air-dried and ground, using a pestle and mortar, to ensure homogeneity; the samples were sieved through a 2 mm mesh sieve and then placed in clean plastic bags and sealed pending digestion and analysis.

Sample Digestion:
For heavy metals determination, portion of the air-dried soil sample (10 grams) were weighed into a Led washed glass and digested, following the method below:

Equipment: Atomic Absorption Spectrometer (IL-257) with background corrector, Stainless steel fume hood to avoid explosive reaction, Teflon beaker (100 ml capacity), Electric hot plate, Volumetric flasks (50 ml capacity), Polypropylene bottles (50 ml capacity)
Reagents: Hydrofluoric acid (HF), 48%, Per chloric acid (HClO4), 70-72%, Nitric acid (HNO3), 10% and 70% solution, Water, redistilled or deionized, Standard stock solutions (1000 ug/ml) of various elements. Digestion Procedure includes:

i. 50g of oven-dry soil, 300 mesh size (0.05 mm sieve opening) was weighed into a 100ml Teflon beaker (Weigh 1.000-5.000 g of organic soil).
ii. 10 ml of conc. HNO3, was added, covered, and boiled gently for about 30 minutes on a hot plate at 100-150˚ C and the contents was allowed to cool.

iii. Treatment of the content with HNO3 followed to destroy organic materials and prevent danger of an explosion by reaction with HClO4.
iv. In a stainless steel fume hood, 5 ml HClO4 and 15 ml HF, was added covered, and boiled gently for 60 minutes on a hot plate at 150-225° C.
v. After 60 minutes the cover was removed and boiling continued until the volume was reduced to 2-3 ml.
vi. It was then cooled and wash down with 5-10 ml of deionized water, covered and boiled for about 20 minutes. Precipitate present was filtered through a What-man GF/B filter. Filtration is desirable to keep the solution free of solid particles that cause clogging of burner capillaries of the atomic absorption spectrometer. Sample solution was washed into volumetric flask and brought up to volume. The contents were then being transferred into 100 ml polypropylene bottles for storage (until determination of elements was made). A 48-hour soak with 10% HNO3 was used for both the preliminary cleaning of new bottles and for routine cleaning.
vii. Standards of elements were being prepared by dilution of stock solution with the same matrix solution as the sample.
viii. The elements were then being determined by atomic absorption spectrometry. Also the reagent blank was being prepared and analyzed

Calculations

$$\text{Mg/kg in soil} = \frac{Reading\ in \frac{mg}{l} \times 50}{wt.of\ sample\ (kg)}$$

$$\% = \frac{Reading\ in \frac{mg}{l} \times 50}{wt.of\ sample\ (kg)}$$

Methods used for the determination of the rest of the parameters were outlined in table XY below.
Sample Analysis:
Descriptive and parametric statistics which include mean, standard deviation, coefficient of variability and Analysis of variance (ANOVA) were employed to summarize the data and determined the differences between the mean groups of the samples. T-test distribution statistics was also used to test the differences in Heavy Metals concentration, Cations, Total Hydrocarbon Content (THC), Anions and other parameters across the sample areas. The data were presented in form of tables. Possibilities at $P < 0.05$ are considered statistically significant.

Furthermore, concentrations of pH, Phosphorus, Nitrogen, Exchangeable Cations (k+, Na, Ca2+, Mg2+), Anions (SO42- , HCO3-, CO3-), Total Organic Carbon, Total Organic Matter, Moisture Contents, Texture (silt, clay, Loam), Electric Conductivity, Total Petroleum Hydrocarbon (TPH), among others were determine using the methods and procedures outlined in Table XY below:

3.5 Table XY: Soil Physico-chemical Parameters and Methods of Laboratory Analysis

Parameters	Method used
pH	pH meter
Texture	Pipet
Phosphorus	Spectrophotometer
Sodium and Potassium	Flame Photometry
Calcium & Magnesium	Versinate Titration
Exchangeable Cations	Ammonium Acetate Extraction
Exchange Acidity	Titration
Cation Exchange Capacity	Sum of Exchangeable Base and Acid
Organic Carbon	Wet Combustion
Nitrogen	Kjeldahl Method
Electric Conductivity	Solu-bridge

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Fe, Mn, Zn, Cu	Atomic Absorption spectrometer
Cadmium, Lead, Chromium	Atomic Absorption spectrometer
(Source: Soil Science Laboratory Manual, Root Crop Research Institute, Umudike, Abia State, Nigeria)	

III. RESULTS AND DISCUSSION

Concentration of the Soils pH, Organic Carbon, Nitrogen, Phosphorus, and Carbon –Nitrogen Ratio of the Sites Evaluated in K-Dere and Environs

This section presents the laboratory results and discussion of the following parameters: pH, Organic Carbon (OC), Organic Matter content of the soils, percentage Nitrogen (N), Phosphorus, and Carbon to Nitrogen ratio of all the four sites sampled in K-Dere and Environs (Details in the Table 4.1.1 below).

A strong relationship exists between soil pH and the solubility of various compounds, the relative exchange capacity and the activity of micro-organisms. Lower pH favors availability, mobility and redistribution of the metals in the various fractions due to increased solubility of the ions in acidic environment (Kinako, 2021).

In the present study, soil pH of all the sites ranged from 5.94±0.42 at Site D surface (control) to 7.16±0.63 at Site A subsurface (15-30 cm depth), indicating a moderate acidic to a neutral reaction (Table 4.1.1). The moderately acidic soil from the control site may tend to have increased micronutrient, solubility, mobility as well as increased heavy metal concentration in the soil (Odu, 2022). Result in the Table 4.1.1 indicated that the soil pH progressively increased with increased assault in the contaminated site. Changes in soil pH have been noted to affect plant growth (Gregorio, 2021). Similarly, the oil wastes encouraged soil moisture retention and increased soil organic matter content. The breakdown of the high organic matter content of the soil by microorganisms being exothermic led to increased soil temperatures observed while the metabolism of the protein content released ammonia (Schnoor et al., 2022). The ammonia dissolved in the available moisture to cause the reported increase in pH value.

Table 4.1.1 Concentration of the Soils pH, Organic Carbon, Nitrogen, Phosphorus, Carbon –Nitrogen Ratio of the Sites Evaluated in K-Dere and Environs

Parameter	Depth	Site A	Site B	Site C	Site D	WHO/FAO Threshold
PH	0-15	7.01 ± 0.12^{cd}	6.88 ± 0.47^{d}	6.87 ± 0.47^{e}	5.94 ± 0.42^{c}	5.5-7.5
	15-30	7.16 ± 0.63^{cd}	7.13 ± 0.17^{d}	7.09 ± 0.23^{de}	6.37 ± 0.18^{c}	
OC (%)	0-15	5.01 ± 0.28^{cd}	6.02 ± 1.49^{d}	6.33 ± 0.97^{e}	2.71 ± 0.42^{d}	4-6
	15-30	5.17 ± 1.20^{cd}	6.13 ± 1.85^{d}	5.6 ± 0.89^{ef}	2.77 ± 0.38^{d}	
OM (%)	0-15	7.06 ± 0.49^{cd}	7.34 ± 1.42^{d}	8.29 ± 1.34^{de}	2.80 ± 0.64^{d}	3-6
	15-30	6.84 ± 0.87^{cd}	7.56 ± 1.90^{d}	7.21 ± 1.41^{de}	2.07 ± 1.16^{d}	
N (%)	0-15	0.94 ± 0.41^{d}	1.09 ± 0.81^{e}	1.06 ± 0.69^{f}	0.57 ± 0.74^{d}	11-13
	15-30	0.98 ± 0.74^{d}	1.08 ± 0.89^{e}	1.03 ± 0.81^{f}	0.68 ± 0.60^{d}	
P (mg/kg)	0-15	76.17 ± 11.36^{a}	62.08 ± 0.62^{a}	78.42 ± 3.97^{a}	37.81 ± 0.98^{a}	10
	15-30	63.87 ± 6.15^{b}	59.03 ± 2.10^{b}	72.36 ± 5.44^{b}	37.11 ± 2.98^{a}	
C/N Ratio	0-15	11.64 ± 2.09^{c}	12.65 ± 0.71^{c}	11.66 ± 0.64^{dc}	13.71 ± 0.71^{b}	11:13
	15-30	13.21 ± 1.47^{c}	13.74 ± 0.61^{c}	13.88 ± 0.88^{c}	14.04 ± 0.95^{b}	

Results are mean+ Standard deviation (SD) of different points of soil sample collection in oil spill polluted soil in K-Dere and environs. Depth of sample collection at each point=0-15cm and 15-30cm. Points with same alphabets are not significantly different (P>0.05)

Results are mean+ Standard deviation (SD) of different points of soil sample collection in oil spill polluted soil in K-Dere and environs. Depth of sample collection at each point = 0-15cm and 15-30cm. Points with same alphabets are not significantly different (P>0.05)

Measurement of soil pH in water, saturated pastes, and solutions of CaCl2 is not satisfactory for non-saline soils (Schofield & Taylor, 2022). Measurements made with glass electrodes or saturated calomel cells yield accurate, reproducible values which are largely independent of the soil-solution ratio, and errors due to the liquid junction potential are minimized because the soil suspensions are flocculated. pH affects the mobility of heavy metals in soil. It has been found that soil pH is correlated with the availability of nutrients to the plant (Gregorio, 2021). Consequently, as pH decreases, the solubility of metallic elements in the soil increases and they become more readily available to plants (Odu, 2021).

4.1.2 Determination of the Soil Organic Carbon and Organic Matter

Soil organic matter comprises all living soil organisms and the remains of previous living organisms in their various degree of decomposition. Soils with organic matter levels above 3.4% are not considered to be vulnerable. This equates to a soil organic carbon content of 2%. Most of our productive agricultural soils have between 3 and 6% organic matter (FAO, 2020). The presence of organic carbon increases the cation exchange capacity of the soil which retains nutrients assimilated by plants.

The concentration of organic carbon (OC) in the soils of the present study were low and some moderate ranging from 2.71±0.42 at site D surface (0-15 cm depth), to 6.33±0.97% at Site C surface (Table 4.1.1). The moderately high amount of organic carbon of the polluted soils may be attributed to the decomposition of plants and animals remains (Leahy & Cowell, 2020). Soil organic matter (OM) enhances the usefulness of soils for agricultural purposes. It supplies essential nutrients and has unexcelled capacity to hold water and absorb cations. It also functions as a source of food for soil microbes and thereby helps enhance and control their activities (Davies et al., 2022). The organic matter content in the soils of the present study varied from 2.07±1.16 at Site D subsurface, to 8.29±1.34% at Site C surface (Table 4.1.1). The polluted soils contain higher amount of organic matter, which may be responsible for the increase in the soil pH as compared to that of the control soil. This observation was supported by Olade, (2022) who reported that oil spilled contaminated sites had significantly higher pH concentration and soil organic matter. Oyedeji (2022) also demonstrated that high OM (>2.0%) in soils is conducive for heavy metal chelation formation.

4.1.3 Determination of the Soil Nitrogen and its Carbon-Nitrogen Ratio.

Nitrogen is the most critical element obtained by plants from the soil and when deficient, it becomes a bottleneck to plant growth. Plants can use the nitrogen as either the cation ammonium, or the anion nitrate. Nitrogen is seldom missing in the soil, but is often in the form of raw organic material which cannot be used directly. Nitrogen is also available in gas forms in the soil, however these quantities are very small and difficult to detect such as: nitrous oxide, nitric oxide, nitrogen dioxide, ammonia and molecular nitrogen present in the air space of the soil. The total Nitrogen content in the oil spill soils of the present study ranged from 0.94±0.41 at Site A surface (0-15 cm depth), to 1.09±0.81% at Site B surface, which is slightly higher than that of the control site (D) which varied between 0.57±0.74 and 0.68±0.60% (Table 4.1.1). The C/N calculated ranged from 11.64±2.09 in oil spilled soils to 14.04±0.95 in control soil. The result of this study is in line with the study carried out by Bundy et al; (2021) who reported that C/N ratio in the topsoil is commonly between 11 and 13 in humid regions.

Onwurah, (2022a) stated that C/N ratio is an index of biomass and they are responsible for the general restoration of microbial flora. Generally, if the ratio is below 20, this is often adequate to satisfy the Nitrogen requirements of micro flora that decompose the residues (Onwurah, 2022a). According to Ngobiri et al. (2022), the low values of C/N ratios showed high decomposition and efficient mineralization process of the polluted area. The oil spilled C/N ratio of the present study ranged from 11.64±02.09 at Site A surface (0-15 cm depth), to 13.88±0.88 at Site C subsurface (15-30 cm depth), and were identified to be lower than that of the control site (D) which ranged from 13.71±0.71 to 14.04±0.95 (Table 4.1.1). Therefore, the effect of the hydrocarbon most likely contributed significantly to the very low levels of these soil properties, and in many cases higher depending on chemical composition and environmental interaction in the area (Field investigation, 2023).

4.1.4 Determination of the Soil Phosphorus

In soil, phosphorus (P) exists in organic and inorganic forms, both of which are important sources of phosphorus for plant and microbial uptake (Leahy and Colwell, 2020). The organic forms exist as phosphates mostly in humus and other organic materials, while inorganic Phosphate are in various combinations of Al, Fe, Mg, Ca and other elements (Lovely, 2022). These are probable sources of the high phosphate concentration observed in the oil polluted areas of this study. It is believed that these increases arose from the activities of hydrocarbon in the area. The high concentration of iron observed may tie-up phosphorus, thus making phosphate ion unavailable to plants (Sihag et al., 2021). Similarly, high soil pH greater than pH 7.3 leads to phosphorus being tied-up as calcium phosphates and made unavailable to plants; this will in effect discourage plant growth.

Moreover, the oil spilled contaminated sites investigated had higher levels of Phosphorus which ranged from 59.03±2.10 at Site B subsurface, to 78.42±3.97 mg/kg at Site C surface, as compared to the control Site which varied between 37.11±2.98 and 37.81± 0.98 mg/kg (Table 4.1.1). The mean concentrations of phosphorus recorded at all the sites were above the WHO/FAO, (2021) permissible limit of 10 mg/kg threshold for agricultural soils (Table 4.1.1). This could be attributed to the presence of high amount of organic matter and plant decomposition (Lytle & Lytle, 2022).

4.2.1 Concentration of the Soil SO42-, HCO3- and CO32, CEC, EA and EC

SO42-, HCO3- and CO32- are the major anions in the soils around the world (Edeogu & Fidelis, 2021). All the samples evaluated including the control sample, the concentrations of these anions were all above 50 meq/l. This was caused by the high concentration of soil pH in the study area. The amount of dissolved organic carbon and anions increased significantly as pH increased. Therefore, the presence of large concentrations of these anions is verse versa. It not only increased pH but also promoted the dissolution of soil organic carbon (AFAR, 2020). Additionally, the concentration of Ca2+ recorded in all the sites is suggested to have modified this effect. Large concentrations of Ca2+ increased the adsorption and reduced the concentration of dissolved organic carbon (Egboka et al., 2021). Anions occur usually in the form of metallic salts and may be supplied in the inorganic forms as potassium chloride (KCl), zinc sulphate (ZnSO4), potassium nitrate (KNO3) and polyphosphates or in the form of mixed fertilizer (Anderson, 2021). Nevertheless, dietary anions have many biochemical effects both in the physiology of plants and man. In plants, some anions are involved in the control of water loss (salt effect), maintaining of turgor and transportation of cations such as potassium, calcium, magnesium, within the plants. Some anions assist in reducing the disease incidence in roots and leaves. Furthermore, their deficiency may cause witting, restricted growth and diseases (Ezeonu et al., 2022). Some anions such as chloride, phosphate and sulphate are acidic and when taken in high concentrations can alter the acid-base load of the body and obviously manifest as net acid load if the diet source does not provide basic cations (K, Ca, Mg) that could balance it (Berardi, 2022).

Cation exchange capacity (CEC) varied between 13.88±1.27 and 90.95±2.40 cmol kg−1. Exchangeable Acidity (EA) levels were moderate ranging from 0.58±0.25 to 1.98±1.22.

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Table 4.2.2: Concentration of the Soil Anions, CEC, EA and EC

Parameter	Depth	Site A	Site B	Site C	Site D (Control)	WHO/FAO Threshold (cmol/kg)
EC (mS/cm)	0-15	700 ± 57.28^{c}	956 ± 92.63^{c}	830 ± 14.14^{c}	198.11 ± 2.98^{b}	
	15-30	736 ± 20.51^{c}	968 ± 93.34^{c}	867 ± 46.67^{c}	205.39 ± 1.96^{b}	20
CEC (meq/100g)	0-15	88.04 ± 4.29^{c}	87.46 ± 3.95^{c}	79.90 ± 0.92^{c}	17.81 ± 1.41^{cd}	
	15-30	75.8 ± 20.81^{c}	90.95 ± 2.40^{c}	75.04 ± 9.94^{c}	13.88 ± 1.27^{cd}	20
EA (meq/100g)	0-15	0.58 ± 0.25^{c}	0.85 ± 0.20^{c}	1.07 ± 0.78^{c}	2.19 ± 0.74^{d}	
	15-30	0.92 ± 0.06^{c}	0.93 ± 0.25^{c}	1.38 ± 0.90^{c}	1.98 ± 1.22^{d}	15
HCO_3^- (meq/l)	0-15	87.38 ± 17.21^{c}	82.14 ± 4.91^{c}	86.76 ± 0.06^{c}	89.84 ± 1.65^{c}	
	15-30	87.88 ± 14.96^{c}	84.76 ± 4.99^{c}	88.25 ± 0.00^{c}	91.11 ± 1.34^{c}	15
TPH (mg/kg)	0-15	14962 ± 4657^{a}	17730 ± 2102^{a}	16553 ± 550^{a}	495 ± 129.30^{a}	
	15-30	25566 ± 1351^{b}	20963 ± 991^{b}	21929 ± 520^{c}	539 ± 88.39^{a}	30
Bulk-density(gm/l	0-15	1.01 ± 0.28^{c}	2.2 ± 0.44^{c}	1.58 ± 1.03^{c}	0.89 ± 0.23^{d}	
	15-30	1.68 ± 1.04^{c}	2.59 ± 0.88^{c}	1.68 ± 1.09^{c}	0.96 ± 0.40^{d}	12
SO_4^{2-}(Meq/l)	0-15	68.89 ± 0.52^{c}	58.46 ± 5.41^{c}	58.53 ± 1.39^{c}	57.46 ± 7.52^{cd}	10
	15-30	68.4 ± 0.23^{c}	60.61 ± 5.10^{c}	60.86 ± 1.05^{c}	59.71 ± 9.23^{cd}	
CO_3^{2-} (meq/l)	0-15	67.51 ± 3.12^{s}	68.8 ± 3.18^{c}	61.57 ± 8.03^{c}	63.09 ± 10.56^{cd}	
	15-30	68.61 ± 3.25^{c}	73.23 ± 7.10^{c}	62.65 ± 4.43^{c}	65.21 ± 6.08^{cd}	15
Moisture (%)	0-15	19.3 ± 3.20^{c}	38.5 ± 10.04^{c}	26.11 ± 7.86^{c}	11.87 ± 1.85^{cd}	
	15-30	20.88 ± 2.43^{c}	39.14 ± 9.70^{c}	27.03 ± 8.18^{c}	12.70 ± 1.86^{cd}	19

Results are mean+ Standard Deviation (SD) of different points of soil sample collection in oil spill polluted soil in K-Dere and environs. Depth of sample collection at each point = 0-15cm and 15-30cm. Points with same alphabets are not significantly different (P>0.05)

Total petroleum hydrocarbon (TPH) concentrations in the contaminated sites were higher compare to the control, indicating high petroleum content in the oil spill sites (Details in the Table 4.2.2). Additionally, all the anions and exchangeable capacity evaluated, both spilled soils and non-spill soils were far above the permissible limits set by WHO/FAO for agricultural soil indicating high contaminants in the present study (Table 4.2.2).

Percentage concentration of moisture content in the oil spill soils were all higher than the control indicating more water contents in the spill soils. This can be attributed to the high level of oil spill in the area, promoted by action of erosions (Table 4.2.2). Soil moisture is necessary for plant water uptake and use, crop yield and productivity. However, too much soil moisture increase soil compaction, soil erosion, loss of seed and reduced crop yield. Nevertheless, low moisture increase leaf diffusion resistance, hindered CO2 diffusion and reduce photosynthetic rate (FAO, 2020).

4.3.1 Concentration of Exchangeable Cations in the Soils Evaluated

All the soils investigated had high Calcium (Ca) values above 4.0 cmol/kg regarded as the permissible limit for fertile soils (WHO/FAO, 2021). Exchangeable potassium (K) varied from 1.33±0.28 at Site A subsurface (15-30 cm depth), to 7.81±2.12 cmol/kg at Site B in the contaminated soils; these are higher than the levels recorded in the control soil (Table 4.3.2), and were above 0.2 cmol/kg which is the permissible limit of exchangeable potassium in agricultural soils (FAO, 2020). Crops planted in such soils may not be productive.

Sodium, potassium, magnesium, calcium and hydrogen are the major soil cations (Davies et al., 2003). They have charges of varying strength which creates antagonistic relationship among the cations, and being in constant competition for available space on soil particles (Berardi, 2022). As a result of this, an excess of one cation leads to a deficiency of another.

Table 4.3.2: Concentration of Exchangeable Cations in the Soils Evaluated

Parameter	Depth	Site A	Site B	Site C	Site D	WHO/FAO Threshold (cmol/kg)
K^{+} (meq/100g)	0-15	2.44 ± 0.11^{d}	7.2 ± 2.90^{c}	4.51 ± 1.55^{e}	0.75 ± 0.69^{d}	
	15-30	1.33 ± 0.28^{d}	7.81 ± 2.12^{c}	3.93 ± 2.09^{e}	0.74 ± 0.81^{d}	0.2
Na^{+} (meq/100g)	0-15	7.58 ± 0.94^{d}	11.12 ± 0.71^{c}	9.62 ± 1.39^{d}	3.10 ± 0.74^{cd}	
	15-30	8.09 ± 2.88^{d}	11.77 ± 0.35^{c}	10.78 ± 1.03^{d}	3.71 ± 0.42^{cd}	15
Ca^{2+}(meq/100g)	0-15	77.76 ± 6.01^{a}	69.74 ± 5.76^{a}	63.21 ± 0.45^{a}	11.43 ± 1.53^{b}	
	15-30	67.61 ± 5.65^{b}	66.88 ± 3.35^{a}	60.1 ± 0.79^{b}	9.74 ± 0.69^{bc}	30
Mg^{2+}(meq/100g)	0-15	35.28 ± 1.32^{c}	32.92 ± 1.88^{b}	31.07 ± 0.63^{c}	19.67 ± 5.58^{a}	
	15-30	30.47 ± 1.37^{c}	34.86 ± 0.22^{b}	29.64 ± 0.18^{c}	19.23 ± 6.82^{a}	10

Results are mean+ Standard Deviation (SD) of different points of soil sample collection in oil spill polluted soil in K-Dere and environs. Depth of sample collection at each point = 0-15cm and 15-30cm. Points with same alphabets are not significantly different ($P > 0.05$)

High soil sodium ion (as obtained in this study) leads to reduced soil permeability resulting to drainage and compaction problems. Plants may therefore not be able to survive the ensuing permeability problems (Tanee & Albert, 2020). The principal cause of soil sodium accumulation has been cited as excess soil bicarbonate and carbonate ions which freely react within soluble soil calcium and magnesium (Tanee & Albert, 2021).

4.4.1 Concentration of Heavy Metals in the Soils Evaluated in K-Dere and Environs

This subsection presents the summary of the mean concentrations of heavy metals (Hg, Fe, Pb, Cu, Zn, Cr, Cd, Ni, Sn and As) analyzed from the soil of various sites sampled. Analysis of variance (ANOVA) revealed a significant variation ($P < 0.05$) in the concentrations of the heavy metal among the sites, which is an indication of the extent of metal pollution in the area. The test revealed that the concentrations of most of the elements were significantly higher at the oil spilled contaminated sites compared to the control site (D) which generally had the lowest concentrations of most of the metals analyzed (Details in the table 4.4.2).

Among the heavy metal analyzed, Arsenic (As) was the least abundant metal recorded in the study area, whereas Lead (Pb) was the highest among the metals with a mean value of 349 mg/kg. Contrary to this finding, Xianjin et al. (2020) reported high concentration of Pb (654.1 mg kg−1) and Sn (660.8 mg kg−1) in simple motor mechanic and machine workshop, respectively. Lead in the soil samples analyzed ranged from 117+6.36 mg/kg at Site D surface (0-15 cm depth), to 349+70.71 mg/kg at Site B subsurface (15-30 cm depth). The mean concentration of Lead recorded at the different sites was above the WHO/FAO (2021) permissible limit of 85 mg/kg threshold for agricultural soils.

ANOVA showed significant differences ($p<0.05$) in the mean concentration of Pb among the sites. The higher concentration of Pb recorded at the oil spilled contaminated sites could be attributed to its sources from sewage effluents, runoff of wastes and atmospheric depositions owing to the close proximity of the sites to erosion prone areas. The mean value of Pb recorded in this study was however; lower than the mean value of 2,645.31 mg/kg reported by Pradhan and Kumar (2021) in an oil spilled contaminated soils in Khan China. This means that the remediation exercise done in K-Dere yielded a very big positive result, and this insight indicated that more remediation exercise should be embarked upon for the total reclamation of the lost soils in the area.

Furthermore, Mercury (Hg) was one of the least abundant metals recorded in the study area. Hg in the soil samples analyzed ranged from 22.65+2.79 mg/kg at Site A surface, to 38.31+0.44 mg/kg at Site B subsurface (Table 4.4.2). The mean concentration of mercury recorded at all the sites were far above the WHO/FAO (2021) permissible limit of 2.00 mg/kg threshold for agricultural soils.

The mean concentration of copper recorded from all the sites ranged from 26.76+7.42 mg/kg at Site D surface, to 63.7+6.63 mg/kg at Site B subsurface (Table 4.4.2). The mean concentrations of copper recorded were above the WHO/FAO (2021) permissible limit of 36 mg/kg threshold for agricultural soils except at Site D (26.76+7.42 and 27.51+7.78 mg/kg) which was below the WHO/FAO (2021) permissible limit. The high concentration of Cu at the oil spilled contaminated soils could be attributed to the effect of the hydrocarbon degradation and gas flaring in the area. This result is similar to the findings of Zhang et al., 2021) which recorded extremely high concentrations of copper at oil spilled contaminated soils, which was beyond the acceptable agricultural soils limits of 50 mg/kg in China.

The mean concentration of zinc (Zn) ranged from 28.60+4.36 mg/kg at Site D surface to 63.21+4.61 mg/kg at Site B subsurface (Table 4.4.2). The maximum mean concentration of Zn recorded at the polluted soils were above the WHO/FAO (2021) permissible limit of 50 mg/kg threshold for agricultural soils, though the difference was little and at site D (control), the mean concentration of zinc recorded was below the permissible limit. The presence of zinc in soil at the various sites could be attributed to the occurrence of the oil spilled pollution. In a similar study, Zhang et al. (2021) reported a mean value of 700 mg/kg for Zn in oil spilled contaminated soils in the area in the year 2006. However, this similar study is an indication that the oil spilled remediation exercise done in K-Dere community, Rivers state, Nigeria was a big success, considering the lower concentration of the parameters recorded at this present study. Zinc is an essential microelement which plays a very essential catalytic role in enzyme reactions but its content varies with the type of soil. High concentration of Zn can, however, pose health threats to humans (Nwilo & Badajo, 2020; Paerl et al., 2022).

Meanwhile, the concentration of chromium (Cr) ranged from 37.01+3.24 mg/kg at Site D subsurface, to 89.65+4.54 mg/kg at Site B subsurface (Table 4.4.2). At all the sites, the mean concentrations of Cr recorded were below the WHO/FAO (2021) permissible limit of 100 mg/kg threshold for agricultural soils. The low concentration of Cr recorded at the all the sites could be due to absence of waste like lead chromium batteries, colored polythene bags, discarded plastic materials and empty paint containers (Jung et al., 2022).

Similarly, the concentration of Cadmium (Cd) ranged from 0.75+0.76 mg/kg at Site D surface, to 1.32+0.98 mg/kg at Site A subsurface (Table 4.4). The mean concentrations of Cd recorded at all the sites were above the WHO/FAO (2021) permissible limit of 0.8 mg/kg threshold for agricultural soils except at Site D (control) which recorded values that were below the WHO/FAO permissible limit (Table 4.4.2). Cd is very much connected with non-residual fractions of heavy metals and thus makes them mobile and potentially bio-available for uptake by plants (Zhang et al., 2021; Johnson, 2022).

The mean concentrations of nickel (Ni) recorded in all the Sites ranged from 16.01+1.40 mg/kg at Site D subsurface, to 31.13+1.25 mg/kg at Site B subsurface. The mean concentration of Ni recorded at all the sites investigated were below the WHO/FAO (2021) permissible limit of 35 mg/kg threshold for agricultural soils.

Table 4.4.2: Concentration of Heavy Metals in the Soils Evaluated in K-Dere and Environs

Parameter	Depth	Site A	Site B	Site C	Site D	WHO/FAO Threshold
Cd (mg/kg)	0-15	0.9 ± 0.50^{e}	1.18 ± 0.51^{f}	1.16 ± 0.76^{d}	0.75 ± 0.76^{i}	0.8
	15-30	1.32 ± 0.98^{e}	1.2 ± 0.52^{f}	1.2 ± 0.78^{d}	0.77 ± 0.75^{i}	
Pb (mg/kg)	0-15	241 ± 54.45^{a}	348 ± 70.71^{a}	302 ± 11.31^{ab}	117 ± 6.36^{a}	85
	15-30	296 ± 45.25^{a}	349 ± 70.71^{a}	309 ± 9.19^{ab}	286 ± 1.41^{a}	
Ni (mg/kg)	0-15	26.85 ± 3.18^{de}	30.11 ± 2.11^{ef}	23.9 ± 1.25^{cd}	15.37 ± 1.21^{h}	35
	15-30	25.71 ± 0.98^{de}	31.13 ± 1.25^{ef}	25.59 ± 1.52^{cd}	16.01 ± 1.40^{h}	
Zn (mg/kg)	0-15	51.58 ± 4.14^{cd}	59.46 ± 4.60^{cde}	57.25 ± 7.34^{c}	28.60 ± 4.36^{fg}	50
	15-30	56.57 ± 5.45^{cd}	63.21 ± 4.61^{cde}	63.04 ± 1.98^{c}	$30.31\pm1.70e^{fg}$	
Fe (mg/kg)	0-15	259 ± 6.93^{a}	287 ± 12.73^{b}	272 ± 6.36^{b}	79.02 ± 0.33^{b}	100
	15-30	247 ± 26.38^{a}	289 ± 11.31^{b}	$264+6.43^{b}$	81.10 ± 0.49^{b}	
Cr (mg/kg)	0-15	87.31 ± 3.95^{c}	87.4 ± 4.02^{cd}	71.51 ± 24.04^{c}	38.14 ± 4.41^{d}	100
	15-30	84.21 ± 7.08^{c}	89.65 ± 4.54^{c}	69.38 ± 23.80^{c}	37.01 ± 3.24^{de}	
Mn (mg/kg)	0-15	206 ± 39.89^{b}	362 ± 0.71^{a}	339 ± 84.15^{a}	57.75 ± 2.11^{c}	0.2
	15-30	210 ± 43.93^{b}	375 ± 5.66^{a}	334 ± 70.71^{a}	53.43 ± 1.90^{c}	
Hg (mg/kg)	0-15	22.65 ± 2.79^{de}	35.14 ± 0.74^{ef}	29.11 ± 4.94^{cd}	33.27 ± 4.33^{defg}	2.00
	15-30	24.32 ± 4.70^{de}	38.31 ± 0.44^{ef}	31.23 ± 2.57^{cd}	35.07 ± 5.39^{def}	
As (mg/kg)	0-15	0.84+1.08e	0.25+0.14f	0.11+0.06d	0.77+1.03i	20
	15-30	1.85+1.36e	0.32+0.45f	0.15+0.09d	0.83+1.10i	
Cu (mg/kg)	0-15	37.91 ± 6.22^{de}	57.8 ± 7.34^{cde}	39.43 ± 1.66^{cd}	26.76 ± 7.42^{f}	36
	15-30	38.69 ± 2.18^{de}	63.7 ± 6.63^{cde}	41.38 ± 1.22^{cd}	27.51 ± 7.78^{fg}	
Sn (mg/kg)	0-15	29.53 ± 2.94^{de}	41.28 ± 1.51^{ef}	33.01 ± 3.95^{cd}	26.89 ± 3.08^{g}	5.00
	15-30	31.02 ± 3.95^{de}	43.7 ± 1.40^{def}	35.87 ± 3.18^{cd}	27.01 ± 4.60^{g}	

Results are mean+ Standard deviation (SD) of different points of soil sample collection in oil spill polluted soil in K-Dere and environs. Depth of sample collection at each point=0-15cm and 15-30cm. Points with same alphabets are not significantly different (P>0.05)

On the other hand, the mean concentration of Selenium (Sn) at the sites ranged from 26.89+3.08 mg/kg at Site D surface, to 43.7+1.40 mg/kg at Site B subsurface (Table 4.4.2). The mean concentration of Sn obtained at all the Site were above the FAO/WHO (2021) permissible limit of 5 mg/kg threshold in an agricultural soil.

The concentration of Arsenic (As) recorded in the soils ranged from 0.11+0.06 mg/kg at Site C surface, to 1.85+1.36 mg/kg at Site A subsurface (Table

4.4.2). The mean concentrations of "As" at all the Sites were far below the WHO/FAO (2020) permissible limit of 20 mg/kg for agricultural soils. This result is in line with the finding of Pradhan & Kumar (2021) who reported the highest mean value of 17.08 mg/kg in oil spilled contaminated soils in South China.

In a nutshell, the oil polluted sites recorded the highest concentration of heavy metals in all the soil samples investigated as compared to the control site (D). The oil spilled effects coupled with gas flaring in the region results in the emission of toxins such as heavy metal in high concentration, thus exposing workers and the communities around to health risk. However, this study is line with the study carried out by Gray et al., (2021), who reported that high concentration of heavy metals is recorded at pollution source especially at oil spilled contaminated areas.

Moreover, the health implications of this is outrageous, heavy metals bio-accumulate over time and toxicity occurs when they accumulate faster than they are metabolized or excreted (Rob, 2020; Eugene et al., 2020). Biological systems possess mechanism for absorption, transportation and excretion of toxic elements. However, at high doses following prolonged exposure, rate of deposition and subsequent absorption may exceed the rate of elimination, leading to toxicity and damage to organs like the lung, liver, kidney, spleen and other target organs. Cadmium, for example, apart from being carcinogenic, long time exposure to it has been associated with renal and biliary dysfunction and lung diseases (Sodipo, 2022). Over 50% of the total burden of cadmium is in the liver and kidney because the metal strongly binds to a specific metal binding protein called metalothionein which is synthesized in both liver and kidney. At the same time cadmium is not easily eliminated from the body as its half-life is over 10years (Atlas, 2022; Compeau et al., 2021). Other metals, such as selenium and nickel also have been reported to cause kidney and liver damage (Rob, 2022). Many elements are classified as essential or toxic. These classifications are further complicated since trace elements which are considered toxic at relatively small doses may be essential and indispensable for normal body function at lower physiological amounts (Schwartz, 2020). For example, arsenic levels above safe limits of 0.01 mg/L (ppm), causes skin lesions, cancer and neurological diseases, while fluoride level above 1.5 mg/L (ppm) causes bone diseases and mottled teeth in humans (WHO, 2020).

4. 5.1 Percentage Texture of the Soils evaluated in K-Dere and Environs

This subsection presents the laboratory results and discussion of the percentage concentrations of Clay, Silt and Sand of all the four sites sampled in K-Dere and Environs (Details in the table 4.5.2 below). The results of the statistical analysis showed that the oil polluted soils had higher Clay (>41 %) and lower sand and silt content than the control site (Table 4.5.2). Soils with higher levels of fine silt and clay usually have higher levels of organic matter than those with a sandier texture. However, unlike plant nutrients or pH levels, there are few accepted guidelines for adequate organic matter content in particular agricultural soils. We do know some general guidelines. For example, 2% organic matter in a sandy soil is very good and difficult to reach, but in a clay soil 2% indicates a greatly depleted situation (FAO, 2020).

The complexity of soil organic matter composition, including biological diversity of organisms, as well as the actual organic chemicals present, means that there is no simple interpretation for total soil organic matter tests.

Table 4.5.2: Percentage Texture of the Soils evaluated in K-Dere and Environs

Parameter	Depth	Site A	Site B	Site C	Site D	WHO/FAO Threshold
Clay (%)	0-15	42.38+3.01^{ab}	41.02+2.26^{a}	64.66+0.78^{a}	28.47+4.72^{b}	50
	15-30	45.63+0.54^{a}	39.36+1.06^{a}	63.78+1.03^{a}	28.84+4.77^{b}	
Silt (%)	0-15	36.87+1.03^{c}	43.11+1.27^{a}	23.48+4.14^{b}	42.01+1.98^{a}	30

	15-30	38.11+0.14[bc]	42.11+0.73[a]	22.41+1.14[b]	42.82+0.98[a]	
Sand (%)	0-15	20.75+4.05[d]	15.87+3.52[b]	11.86+4.92[c]	29.52+2.09[b]	25
	15-30	16.26+0.68[d]	18.6+1.79[b]	13.81+2.17[c]	28.35+3.78[b]	

Results are mean+ Standard deviation (SD) of different points of soil sample collection in oil spill polluted soil in K-Dere and environs. Depth of sample collection at each point=0-15cm and 15-30cm. Points with same alphabets are not significantly different (P>0.05)

It is also known that soils higher in silt and clay need more organic matter to produce sufficient water-stable aggregates to protect soil from erosion and compaction. For example, to have an aggregation similar to that of a soil with 16% clay and 2% organic matter, a soil with close to 50% clay may need around 6% organic matter (FAO, 2020).

Organic matter accumulation takes place slowly and is difficult to detect in the short term by measurements of total soil organic matter. However, even if you do not greatly increase soil organic matter (and it might take years to know how much of an effect is occurring), improved management practices such as adding organic materials, creating better rotations, and reducing tillage will help maintain the levels currently in the soil. And, perhaps more important, continuously adding a variety of residues results in plentiful supplies of "dead" organic matter—the relatively fresh particulate organic matter that helps maintain soil health by providing food for soil organisms and promoting the formation of soil aggregates.

IV. SUMMARY, CONCLUSION AND RECOMMENDATIONS

SUMMARY

All the four sites sampled, the levels of heavy metal were far above the WHO standard. All the oil spilled sites had higher Clay (> 41 %) and lower sand and silt contents than the control site. Soil mean pH varied between 5.94±0.42 in the control and 7.16±0.63 in the oil polluted soils. Soil reactivity is dependent on pH, ranges of pH in soils from 3.5 (very acid) to 9.5 (very alkaline). The effect of pH is to remove from the soil or to make available certain ions. Soils with high acidity (<5.5) tend to have toxic amounts of aluminum and manganese. Soils with high alkalinity (> 8.5) tend to disperse. Soil organisms are hindered by high acidity, and most agricultural crops do best with mineral soils of pH 6.5 (FAO, 2021). The soil pH of the soils evaluated, all not favorable.

Total nitrogen (N) content of the oil spilled soils ranged from 0.94±0.41 to 1.09±0.81% and is slightly higher than that of the control soil. This is reflected in the high value of organic matter (8.29±1.34%) in oil spilled soils. Available Phosphorus was quite high ranging from 59.03±2.10 to 78.42±3.97 mg/kg in the oil spilled soils. Cation exchange capacity (CEC) varied between 75.04±9.94 and 90.95±2.40 cmol kg−1. All the anions and exchangeable cations (Ca, Mg, K and Na) evaluated were far above the permissible limits set by WHO/FAO for agricultural soil. Average levels of Pb ranged from 241±54.45 to 349±70.71 mg/kg in the oil spilled soils and 117±6.86 to 286±1.41 mg/kg in the control. Mean concentration of Cr in the oil spilled soils varied between 69.38±23.80 and 89.65±4.54 mg/kg, and is slightly higher than the control (38.14±4.41 mg/kg), while Cd was found in trace amounts (0.9±0.50 and 1.2mg/kg). These values are all far above the maximum tolerable limits set by FAO/WHO for agricultural soil.

In general, the oil spilled effects coupled with gas flaring in the region results in the emission of toxins such as heavy metal in high concentration, thus exposing workers and the communities around to health risk (field investigation, 2023). Cadmium, for example, is known to be harmful to the kidney; mercury impairs the central nervous system, while benzene is carcinogenic (Ikamaise et al., 2022). Other components of the oil spill effect that may be injurious to both humans and animals include some heavy metals or chemicals from germicides, fungicides and herbicides, employed in agricultural activities, trace metals and macronutrients such as Potassium (K), Magnesium (Mg), Calcium (Ca), strong acids, or alkalis, halogens, acid compounds, which may be constituents of pesticides (Jung et al., 2021). These chemicals may damage the general ecosystem as well and change the composition of the ecosystem in this particular environment. The effect created by such phenomena bury crops, lands, houses, water, schools, roads and animals, rendering K-Dere region almost completely unsuitable for human and animal habitation.

However, the observations so far have revealed that Oil spill assault has serious public health implication as it is capable of causing several health problems such as lung cancer, renal failure, infertility, cough, asthma, pneumonia, bronchitis among others. Based on these findings, it was concluded that Oil spill assault in K-Dere has serious negative impact on the environment and public health.

Consequently, government at all levels, non-governmental organizations, religious groups and all stakeholders should step up efforts in addressing these issues of public health as a means of having a healthy society.

CONCLUSION

The result of this present study does not mince words on the implications of the oil spill for local populations in the area. It concludes that people in communities around oil facilities have been living with chronic exposure to pollution that spans up to forty years. This is equivalent to the full lifespan of Nigerians in rural communities. In a context where the findings of oil pollution are extensive and its damage is found to be wide ranging, as it were in K-Dere. The impact of clean up exercises is vital. The findings by UNEP from remediated' sites have implications across the Niger Delta. UNEP found that at a number of sites soil pollution has penetrated to 5 meters or more in depth.

The levels of persistent pollution appear to be damning. At four sites sampled, the levels of heavy metal were far more than the WHO standards. The report from UNEP highlights that despite the extraordinary levels of pollution, there is still ongoing damage from a variety of sources, and almost all actors share responsibility for the ongoing spills, ranging from 'operational failure' through to criminal damage. However, the eagerness with which parties seek to apportion blame for pollution to each other without taking responsibility for their own is something that should be condemned. All actors must face this issue squarely, from oil operators whose facilities are simply insecure, through to security agencies and communities who must find the will to act against a criminal industry that does extensive damage for the community as a whole.

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